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Thesis for the Degree of Master of Fisheries Science

Acoustical Survey for Estimating Fish Biomass at Chilam Bay, Korea

by

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KOICA-PKNU International Graduate Program of Fisheries Science

Graduate School of Global Fisheries

Pukyong National University

February 2019

Acoustical Survey for Estimating Fish Biomass at Chilam Bay, Korea

칠암항에서의 음향 자원 조사

Advisor: Professor SHIN Hyeon-Ok

by

Nduwayesu Evarist

A thesis submitted in partial fulfilment of the requirement

for the degree of

Master of Fisheries Science

in KOICA-PKNU International Graduate Program of Fisheries Science,

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Acoustical Survey for Estimating Fish Biomass at Chilam Bay, Korea

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February 22, 2019

Table of Contents

PUKYONG NATIONAL UNIVERSITY 부경대학교

List of Figures

List of Tables

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List of Acronyms and Abbreviations

BW	Body Weight
CF	Conversion Factor
dB	Decibel
DGPS	Differential Global Positioning System
EDSU	Elementary Distance Sampling Unit
FL	Fork Length
GPT	General Purpose transceiver
kHz	kilohertz
MRA	Marine Ranching Area
NASC	Nautical Area Scattering Coefficient
nmi	Nautical miles
NTU	Nephelometric Turbidity Units
RCM	Recording Current Meter
SV	Volume Backscattering Strength
TL	Total Length
TS	Target Strength
TVG	Time Varied Gain
UTM	Universal Transverse Mercator

Acoustical Survey for Estimating Fish Biomass at Chilam Bay, Korea

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Abstract

Acoustics is effective method in fisheries research studies involving direct biomass estimation. Fish biomass change in space and time and fish populations dynamics are attributed to under water construction with artificial reefs in marine ecosystem. This study estimated fish distributions, determined catch composition, and biomass changes in small scale marine ranching area during daytime and nighttime using the scientific echo sounder and the gill net. Fish were densely distributed in pelagic zones during nighttime than daytime where few fish schools were scattered near sea bottom. In each season's gill nets 15 different groups of fish species were caught and their estimated average target strengths were -44.0 dB and -44.4 dB for autumn and winter surveys, respectively. The autumn biomass were 7.7 and 26.0 tons during daytime and nighttime, respectively. Winter had

2.27 and 30.97 tons during daytime and nighttime, respectively. Different species are more active at night, and exhibit movements and behaviours thus occupy varying water zones. This explains the varying estimated biomass with seasons and time of surveys around artificial reefs. Comprehensive studies about fish biometrics and demersal species to accurately estimate entire biomass of all fish species in Chilam Bay will be carried out in future.

Key words: Acoustical survey, Chilam Bay, Split beam, Target strength, Fish biomass

Introduction

Fisheries acoustics is effective in research activities to estimate fish biomass, abundance, fish density, temporal and spatial distributions of fish species (Simmonds and MacLennan, 2005; Andrij *et al*., 2016). Split-beam system is one of the echosounders used in fisheries research, when compared with others it has greater advantages in direct measuring of target strength (Chu, 2011). The split-beam echosounder is more effective, and uses both amplitude and phase information that makes it comparatively better in phase differences between adjacent transducer quadrants than a dual beam (Foote, 1987). All four quadrants of the split beam function as transmitters and receivers of backscattered signals simultaneously, the signals are received independently forming four beams with two perpendicular to one another. During determination of angles that give the position of fish, the beam signals are applied to the whole transducer. The beam echoes are received from each quadrants, however processed separately in the receiver (Muhammad, 2017).

Using acoustics during fisheries data collection is precise, saves time and does not affect the fish habitats. The scientific echo sounder during experiment sends the electrical energy from the transmitter to the transducer which converts it into sound energy and then this energy is projected in water column vertically downwards until it meets the barrier, individual fish or fish schools, planktons and sea bottom as targets (Simmonds and

MacLennan, 2005). This energy on meeting the target, it returns as echoes to the transducer which converts it back into the electrical energy (Burczynski, 1982). The receiver amplifies and modifies the received electrical signals to form suitable output as signals that represent the target under study on computer display. The signals on the display monitor usually appear as short pings on the paper recorder (Parker *et al.,* 2009). The pulse of electrical energy is reduced each time the transmitter is triggered and has a particular pulse length for transmitting electrical signals (Simmonds and MacLennan, 2005).

Target strength is a pre-requisite for fisheries acoustical surveys (Barange and Soule, 1996). TS is the measure of the reflection coefficient of a sonar target usually quantified in decibels (dB). Fish target strength is determined through, in-situ method, ex-situ and the use of mathematical models to develop target strength from backscattering coefficient characteristics of targeted fish species (Chu, 2011). TS varies depending on presence of swim bladder, fish size, fish behavior, morphology and physiology of fish, also depends on aspect angle at which the signal hits fish and the tilt angle to the transducer (Simmonds and MacLennan, 2005; Burczynski, 1982). To estimate the target strength of fish species, the echoes received to the transducer have to be independent in range and position of fish in the beam. The range at which targeted fish species are located in water column is determined by the time required for the acoustic energy to travel from the transducer to fish or fish schools and then back to the receiver (Johannesson, 1983).

Signal processing by echo integration method, is where acoustic signals from fish schools or many fish species are collected, analyzed, and resolved as individual fish targets

(Simmonds and MacLennan, 1992). This technique is based on the principle that acoustic intensity reflected by a target is proportional to the numbers of the fish targeted and the mean backscattering strength and cross section, related to the target strength of fish (Burczynski, 1982). TS measurements are required in the calculation of CF for use in biomass estimation. When echoes from the particular targeted fish arrives at the receiver, the corresponding mark appears at a distance below the transmission line which is proportional to the range of the target from the transducer. Echo signals from multiple targets like fish schools combine together to produce strong marks which appear as clouded or red spots on the echogram. The marks on the echograms are based on threshold adjustments for the targeted fish species during calibrations before the surveys. However the echogram is limited to provide other required information about targeted fish species, therefore other surveys like gillnet experiments, trammel nets, fish traps are important to provide fish catches and information for understanding species composition, size structures, distributions and environmental monitoring through water quality parameters.

Fish biomass change with time and space, Hilborn and Walters (1992) explained the factors attributed; fish stock sizes, fish populations, fishing pressure, fish mortalities, fish movements and migrations, reproduction and recruitments. Direct fish biomass estimation with acoustics is one of the stock assessment methods to assess fisheries productivity, aquatic biodiversity interactions with ecosystem (Jung *et al*., 2011, Egerton *et al.,* 2018). The ecological factors of fisheries including food abundance, good water quality parameters and species distribution indicate ecological interactions. The fisheries status

(Jorgensen *et al.,* 2016; Hale *et al.,*2008) explained this in terms of fish biomass, fish population dynamics. Some of these factors are influenced by artificial reefs through under water construction (Mark and James, 1989). Artificial reefs are constructed and installed in water environments, and Chilam-Gijang small scale marine ranching area has several artificial reefs deployed and might have influenced fish distributions, fish biomass and abundance in this modified water ecosystem.

Chilam Bay is located at the Coast of East Sea of Korea, and Gijang marine ranching area is part of that bay where several artificial reefs have been deployed. Underwater construction with artificial reefs influence fisheries productivity and restore fish habitats (Charbonnel *et al.,*2002; Grossman *et al.,*1997). Artificial reefs mimic the structure of natural habitats, and ecology which suite biodiversity interactions in an aquatic ecosystem. The ongoing coastal developments, commercial fishing activities might have altered the fish habitats. Okamura *et al.,* 2016) reported the nucelar effluents from nuclear power plants, radiations, water temperature changes as ocean water is used as a coolant of machines in nuclear power plants. Gijang marine ranching area is surrounded by these nuclear power plants and ongoing fishing activities in Chilam Bay affect the marine ecosystem. Mark and James (1989) explained the influence artificial reefs have on fish biomass, distributions and abundances in the ecosystems. The expanded habitats with artificial reefs inhabit fish, become the spawning and nursery grounds for fish and attract fish foods. Jung *et al*., (2011) and Egerton *et al.,* (2018) explained the fisheries productivity and biodiversity interactions within the ecosystem.

The ongoing research activities are aiming to restore, protect and preserve fisheries resources in the small scale marine ranching area of Gijang, while economically exploiting aquatic resources. Artificial reefs in Gijang marine ranching area are hypothesized to have influenced fish distributions, species composition and biomass changes that depict the fisheries productivity. This study aimed at estimating fish distribution and biomass change using the scientific echo sounder with 120 kHz split beam (Simrad EK60, Norway) The field surveys collected acoustical and ecological data for the fish abundance around Chilam Bay during daytime and nighttime of autumn and winter seasons. The study was guided by the following objectives;

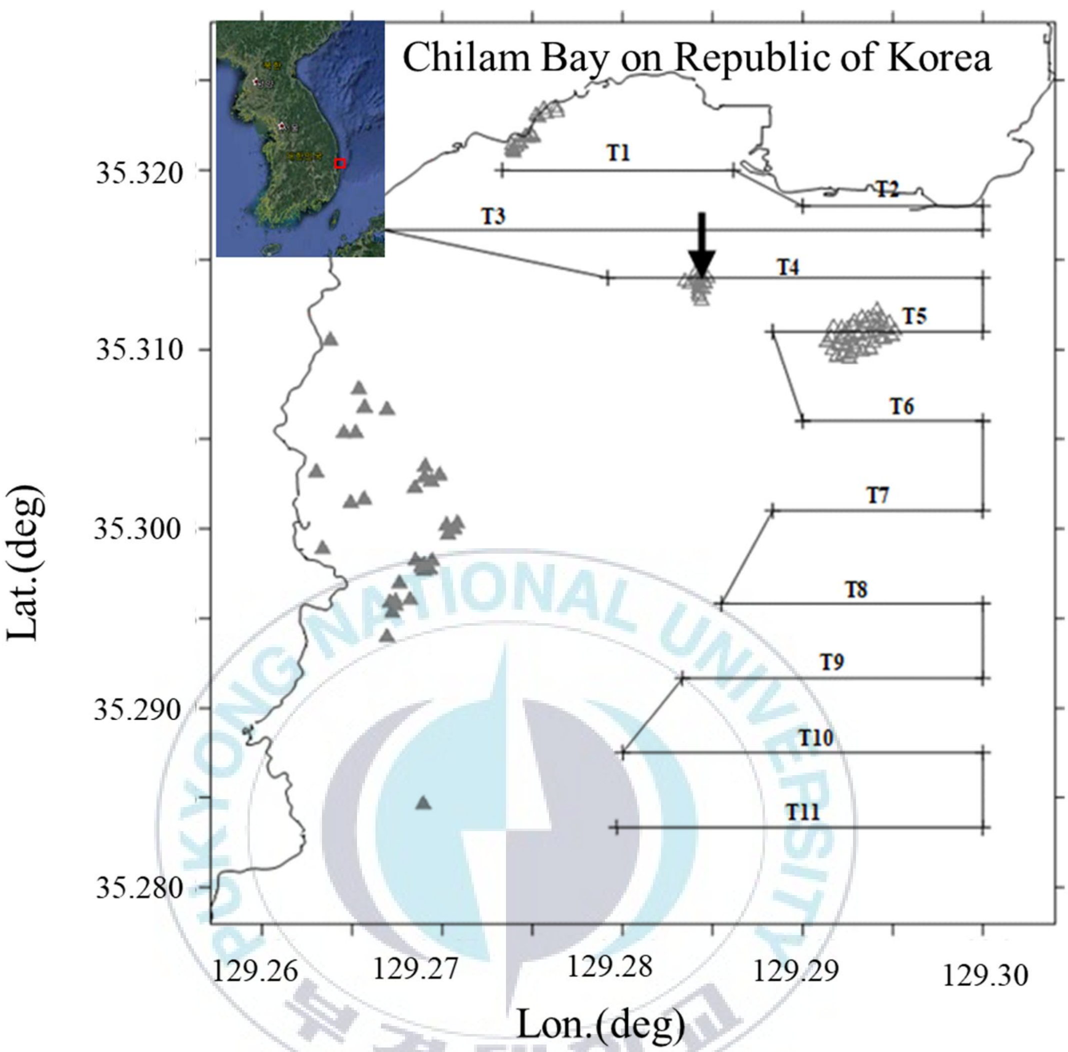
1) Estimating fish density distribution during autumn and winter seasons in Chilam Bay.
2) Determining the catch composition and estimating target strength of the pelagic species caught by gill nets in Chilam Bay.
3) Estimating the fish biomass changes during daytime and nighttime of autumn and winter seasons in Chilam Bay.

The generated data and information about fish density distribution, species composition and fish biomass change in different fishing seasons of the year. This information could be used to make guidelines about sustainable exploitation of fisheries and management of aquatic systems by the fisheries stakeholders of Chilam-Gijang marine ranching area.

Materials and methods

2.1. Scope and area of study

The study was carried out at the small scale marine ranching area in Chilam-Gijang, the coastal area of East Sea, Korea on 23rd/September/2018 and 11th /November/2018. The study area and transect design for acoustic survey, water environmental monitoring and gill net surveys were as shown on Fig.1. Aglen (1989), reported about the degree of coverage during fisheries acoustic data collection for proper biomass estimation in the total surveyed area. The marine ranching area has about 840 hectares and the total of 11 systematic parallel grids were designed to cover the study area. During two different fishing seasons of autumn and winter in 2017, transects with GPS coordinates 35.1924° N, 129.1653 ° E and 35.1915° N,129.1714° E transect 1 and 35.1704° N, 129.1667° E and 35.17.00° N,129.18.04° E transect 11 (Figure1). The acoustic surveys were conducted using the scientific echo sounder with 120 kHz split beam (EK60, Norway) in different fishing seasons. During data recording the echo sounder was deployed at water depth of 1.5 m from surface to collect fish acoustic signals during both daytime and nighttime on sampling days.



Key
▲ and △ : Location of artificial reefs
– : Survey line
T : Location of each surveyed transect
↓ : Location of fish finder

Figure 1. Acoustical study area in the marine ranching area of Chilam-Gijang.

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2.2. Methodology of data collection

2.2.1. Fish species catch composition and target strength.

The experimental gillnets were set in two months of August (Autumn season) and November (start of winter season) using lantern type of fishing gear to obtain the fresh fish samples for determining the catch composition, and TS estimation. The gill nets were set at four sampling stations in Chilam Bay (Jangan) fishing grounds. In the study site, there was underwater construction with several artificial reefs (Sandstone, Square, Octagonal and Natural rock) distributed, these had been deployed to improve the fisheries productivity in this marine ranching area. From each fishing ground the caught fish samples were identified and sorted into taxon. Total length (cm) and weight (g) were measured for each individual fish and then recorded on the fish biometrics form. The individuals of fish samples were weighed (0.1 g resolution) using a digital weighing scale and the total length / fork length (1.0 cm resolution) using a 100 cm measuring board.

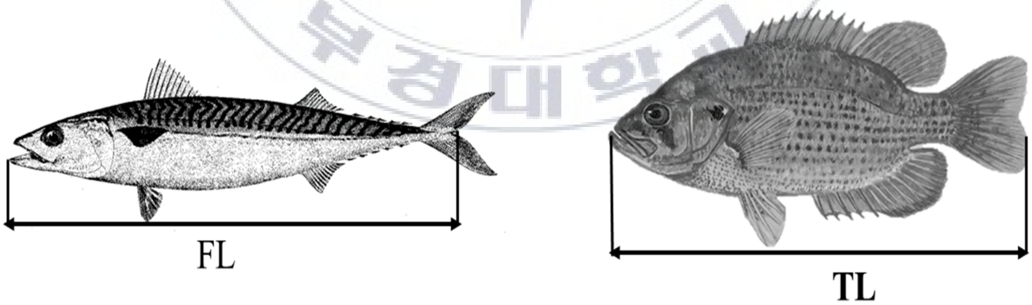

Figure 2. Body length for the forked and non-forked fishes.

2.2.2. Monitoring water environment at the water depth of 5 m in Chilam Bay

The current meter (RCM9, Aanderaa, Norway) was tied on water floats and lowered vertically into water at a depth of about 5 m around one of the sampling station to get the environmental water parameters on 11th November, 2017. The water parameters were recorded within 10-minute interval in Chilam Bay. The data recorded with the memory of RCM 9 included; current speed and direction, conductivity, turbidity, dissolved oxygen, water temperatures and pressure. These recorded water environment parameters are important during fish acoustic data recording, acoustic survey design and also are vital as they influence the biological behaviours of different fish species. The environmental water parameters were monitored for three hours around the sampling stations.

Table 1. Water parameters at the water depth of 5 m around one sampling station

Water parameter	Value
Temperature (°C)	17.6
Dissolved Oxygen (m/L	8.6
Turbidity (NTU)	1.0
Salinity (psu)	33.5

2.2.3. Acoustic data collection

The scientific echo sounder (EK60, Simrad Co., Norway) with the frequency of 120 kHz split beam and side-scan sonar (Elite Ti, Lowrance, USA) were used to collect acoustic data from fish and the shapes of sea bottom in the Chilam-Gijang marine ranching area. The integrated system consisting of a transceiver, a control unit (GPT) and a display unit, received the electric power from a large quantity Li-ion battery (12V 117 Ah) and an electric inverter supported the system.

Table 2. Calibration parameters for acoustical fish surveys on 23rd September, 2017 and on 11th November, 2017

Parameter	Value
Frequency (kHz)	120
Transmitted Power (W)	200
Absorption coefficient (dB m^{-1})	0.0374
2 way beam angle (dB re 1 steradian)	-20.7
Beam width (-3dB)	Along 7.0, Athwart 7.1
Pulse duration (µs)	512
Sound speed (m/s)	1494
Transducer gain(dB)	25.40

The transducer was deployed by the Pole mount method, and in this setup, a pole was mounted, and then transducer fixed at the base plate, two ropes were tied at each end of the transducer. This assured the transducer stability and flexibility during the survey and then a pole was affixed onto the transducer and two suspension ropes on port side of vessel, where each rope was tied on each side transducer pole, and then adjusted. These ropes were tied on two sides of the ship and fixed firmly on the pole-transducer system. The echo sounding system except the transducer was deployed at 1.5 m below water surface on the port side of the vessel during acoustic data recording. The data were recorded using a high DGPS at the same time identifying the images of the sonar with the echograms received from a scientific fish finder.

2.3. Data analysis

The computer's windows XP was used and raw datasets were imported into echoview 3.30.60, the calibration parameters (Table 1) were applied to adjust echoview settings for further data analysis. The raw data variables were displayed in angular positioning raw pings T1, SV raw pings T1, TS raw pings T1, position GPS fixes and vessel logs. The cruise tracks, echograms were displayed and then setting and marking the surface and bottom lines, EV file properties were selected and transducer depth fixed to 2.0 m depth. The bold green line appeared below the surface line on the echogram. Making the bottom line for editing and one existing lines was sound detected bottom. The distance from sea bottom was estimated to -0.20 m above the yellow line. The bold green line appeared above the sea bottom line on the echogram. The variable properties were selected to create the nautical mile grid on the echogram, the -70.0 dB used. The time and distance between grids GPS distance 0.10 nautical miles was used and the depth separation range of 50 m surveyed area depth. The sea bottom and top lines were edited, sea bottom line was connected and repaired. The air bubbles near the sea surface, bad data regions were marked and deleted from the echogram. The scattering acoustic characteristics of the fishes detected in the acoustic beam, that is, the experimental TS–length conversion formulae (TS = 20 log TL - 72), was used to estimate the size of fish. Data analysis through echo integration, and the regions above surface and below sea bottom lines were excluded as bad data regions. Then the data was exported as csv excel files into Surfer software with column layers; the *SV*_mean, NASC, Lat-M and Lon_M and time for EI_Kijang-20170923 and EI_Kijang-20171111.The separate echograms were generated, EI_Kijang-20170923 (day and night) and EI_Kijang-20171111 (day and night) for autumn and winter surveys respectively.

From each echogram the NASC used to determine the number of data per transect from T1 up to T11 for all four surveys. The map converter was used to convert the GPS coordinates into UTM for each survey line. The generated lon-lat-txt files had the column values for x 100,000 and the x, y and NASC. These excel files were imported into surfer program and then base map, the map overlay formed to generate the NASC distribution maps. The fish distributions per surveys line ranged from 1 to 50000 m^2/n.mile^2.

The volume scattering intensity of the echo sounder was based on acoustic integration theory and volume scattering strength. During analysis the mean volume scattering intensity was obtained as $<SV>$, the distribution density of fish $<n>$ samples, the averages of fish acoustics were as in equation (1), below in relation with target strength.

$< SV > = < TS > +10 \log 10 (< n >)$ (Simmonds and MacLennan, 2005) (1)

The standard units used in fisheries acoustics and the acoustic indexes of acoustic intensities within surveyed cross-sectional area, and as expressed in dB. The scattering strength, the area intensity scattering factor were measured in nautical mile^2 (n.mile^2) which are Nautical Area Scattering Coefficient, NASC, m^2/n.mile^2), and the relationship between volume scattering intensity and NASC is as expressed in equation (2) below. Where $r1$ and $r2$ are the integrations from the start and end of each surveyed transect respectively.

$NASC = \pi\ 1852 \int_{r1}^{r2} S_v\, dr$ (Burczynski, 1982) (2)

Acoustic reflection intensity TS of the targeted fish depend on the scattering cross sectional area which explains the concepts of the relationship between the fish length (TL cm) and mean sound scattering intensity averaged over the swimming tilt angle (3).

$TS = 20\ log\ (TL) - 72$ (Simmonds and MacLennan, 2005) (3)

The relationship between TS and back scattering cross-sectional area (σ) is expressed as in equation (4) below.

$\sigma = 4\pi\ 10^{\frac{TS}{10}}$ (Burczynski, 1982) (4)

Therefore the nautical area scattering coefficient (NASC) is divided by the scattering cross-sectional area (σ), expressed as the distribution density (n) of the targeted fish population per n.mile^2 (5).

$$n = \frac{NASC}{\sigma} \qquad \text{(Foote, 1987)} \qquad (5)$$

To find the relationship between the total length (TL) and the weight (BW) as seen in equation (6), can be obtained by using regression analysis to obtain a_f as the intercept from ant logarithimic equation as (6) below.

$$\text{BW} = a_f \text{TL}^{bf} \qquad \text{(MacLennan \& Simmonds, 1992)} \qquad (6)$$

Where af and bf are the constants for each target species and if the target strength of each fish species is known, then;

The logarithmic equation was used to relate the fish weight with TS from the linear expressions as shown below.

$$\text{September} < \text{TS}_{120\ \text{kHz}} > = 20 \log\ (\text{TL}) - 72\ ,\ \text{W} =\ 0.0328\ \text{TL}^{2.7537} \quad (7)$$

$$\text{November} < \text{TS}_{120\ \text{kHz}} > = 20 \log\ (\text{TL}) - 72\ ,\ \text{W} = 0.0135\ \text{TL}^{2.9857} \quad (8)$$

Where TS was the Target Strength from the split beam echo sounder basing on the echo integration method expression. The TS was used to relate with conversion factor which was used in estimating fish biomass (MacLennan & Simmonds, 1992; Foote, 1987).

$$TS = 10\log(\frac{\sigma}{4\pi}) \qquad \text{(MacLennan \& Simmonds, 1992)} \qquad (9)$$

Hence the fish biomass estimation (biomass, g/m^2) has the following relationships as in equations (10), where ρ is the biomass density.

$$\rho = \frac{NASC}{\sigma}.w \qquad \text{(Parker } et\ al.\text{, 2009)} \qquad (10)$$

$$= \frac{a_f L^{bf}}{4\pi 10^{(TS/10)}}\ .NASC$$

From the equation (10), the NASC value is on the right hand side as shown and this is called the conversion factor (CF) used to calculate fish biomass, ρ (g/m^2), the average biomass density ($\bar{\rho}$) obtained from the selection of each weighted mean, to get the overall fish density respectively as in equation (11) below.

$$\bar{\rho} = \frac{\sum_{i=1}^{N} \bar{\rho} \bullet ni}{\sum_{i=1}^{N} ni} \qquad \text{(Parker } et\ al.\text{, 2009)} \qquad (11)$$

In this case ($\bar{\rho}$) is the average density of the ni^{th} line with the total data recorded in m^2/n.mile^2. $Var(SA)$ is the variance of mean biomass density and the total amount of biomass (B) as expressed in equation (14) below;

$$var(SA) = \frac{Q}{Q-1} \bullet \frac{\sum_{i=1}^{N} di(SA_i - SA)^2}{\left(\sum_{i=1}^{N} ni\right)^2} \qquad \text{(Parker } et\ al.\text{, 2009)} \qquad (12)$$

$$\bar{S}A \pm 1.96\sqrt{Var(SA)} \qquad \text{(Parker } et\ al.\text{, 2009)} \qquad (13)$$

B = [(Area*100)^2 ($Var(SA)$)] (Burczynski, J. 1982) (14)

Where A: total surveyed area (m^2), Q: backscattering cross section area, *n_i th, d: fish distributions (m^2 /n.mile^2), d_i: mean fish density, S: ratio of mean fish density and surveyed area multiplied by (π) to get the coefficient of variation for each periods' surveys. When basing on the catch composition of fish species and acoustic scattering characteristics of each targeted fish species, the distribution of fish species can be established. Assuming that the area scattering coefficient by the fish species is $NASC_i$ can be obtained as in equation below.

$$NASCi = \frac{w_i < \sigma i > NASC}{\sum_{k=1}^{n} w_k < \sigma_k >}$$

(Burczynski, J. 1982) (15)

$NASC_i$ is the area scattering coefficient for the entire surveyed area, n is the number of captured species, w_i is the type of species, and < σ_k> represents the average acoustic scattering cross-sectional area of fish species.

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Results

3.1. Echograms of the fish schools in the surveyed areas during daytime and nighttime of different seasons.

During seasons of autumn and winter, the area surveyed consisted eleven transects (T1-T11) in each survey season. During autumn daytime surveys, few fish schools were scattered near the sea bottom as compared to the nighttime surveys when the fish schools were distributed in the pelagic zone. Nighttime fish schools were more densely scattered in the pelagic zones from transects T6 to T11 and few from transects T1 to T6. The fish schools assemblages on the echogram were displayed as deep blue regions. The black patches and pale white regions on the echogram represented the individual fish or small fish schools with low scattering intensities especially between transects T1 and T6 (Figure 4 and Figure 5).

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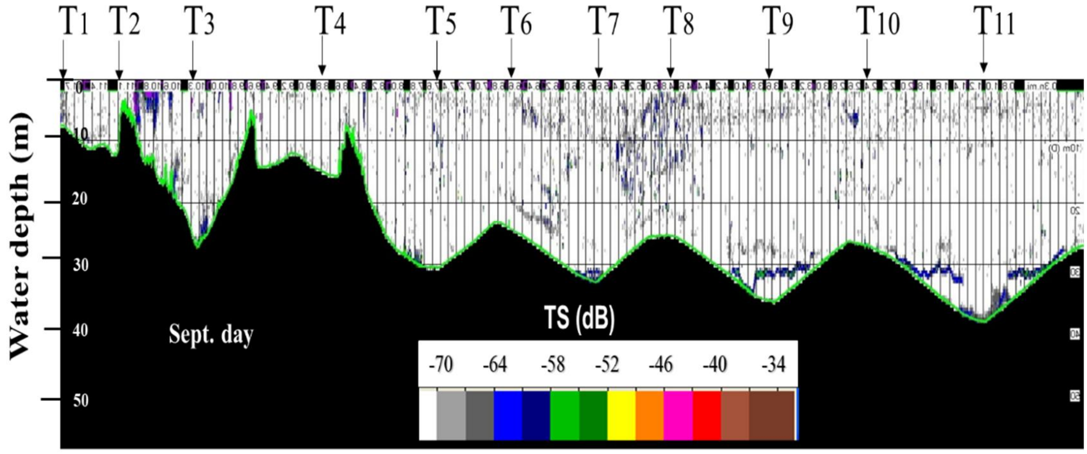

Figure 3. Echogram of the TS values during daytime surveys of autumn season for transects T1 to T11 in Fig.1.

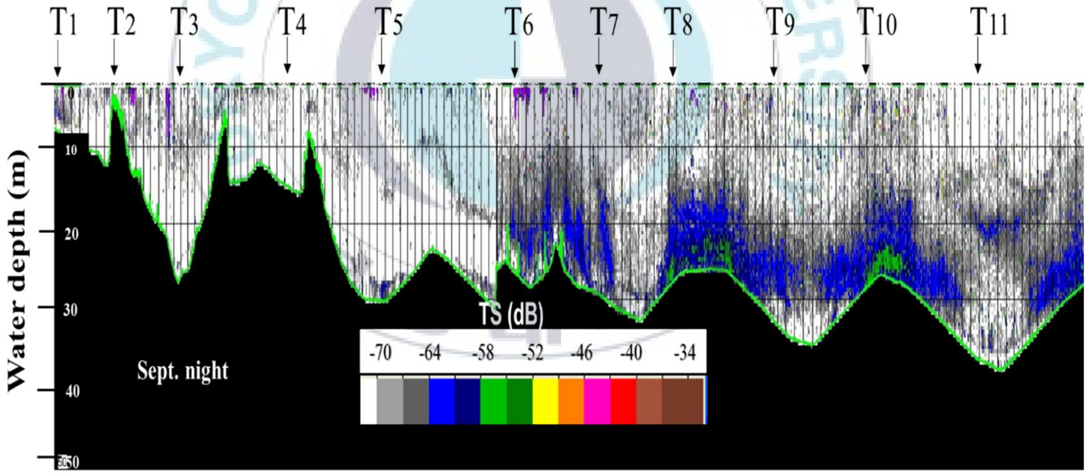

Figure 4. Echogram of the TS values during nighttime surveys of autumn season for transects T1 to T11 in Fig.1.

Daytime of winter surveys between transects T1 and T4 had few fish schools in the pelagic zone as compared to nighttime where there was no any fish. Near the sea bottom around the same transects there was no fish schools during both daytime and nighttime surveys. From transects T5 and T11 the fish schools were densely distributed vertically in the pelagic zone and near the sea bottom. Fish schools assemblages were represented by the red or deep blue regions which meant presence of high echo scattering intensities and the scattered black spots or pale regions (Figure 6 and Figure 7) represented few fish schools or individual fishes. Generally the surveys of winter had the lower echo scattering intensities as compared to the autumn surveys. Across echogram, the winter fish schools were densely distributed near the sea bottom than the autumn fish schools during nighttime surveys.

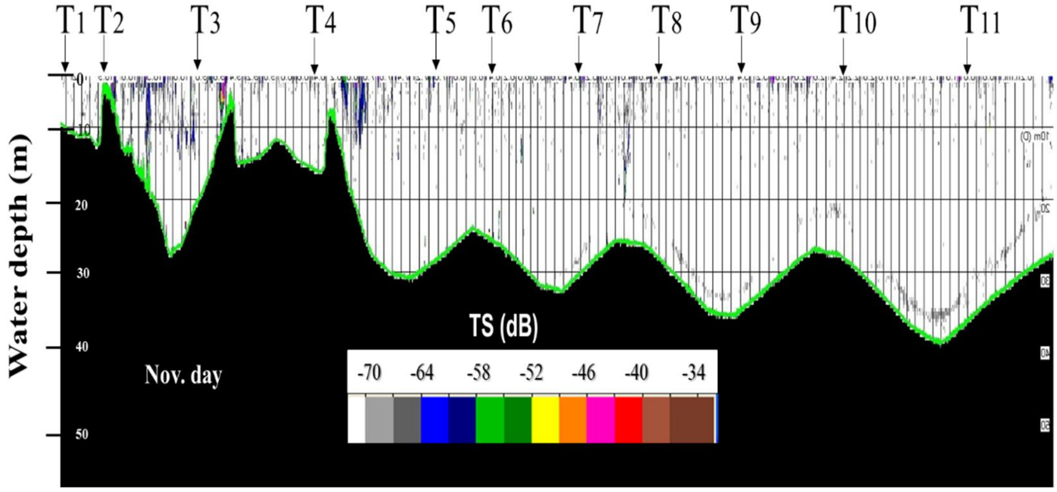

Figure 5. Echogram of the TS values during daytime surveys of winter season for transects T1 to T11 in Fig.1.

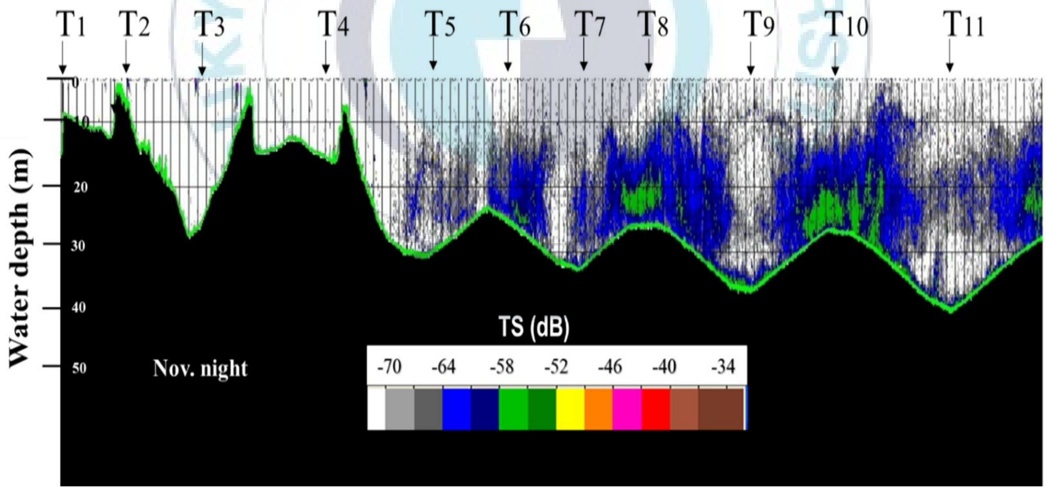

Figure 6. Echogram of the TS values during nighttime surveys of winter season for transects T1 to T11 in Fig.1.

3.2. The NASC distribution maps of autumn, winter and time period of Surveys

The study area of Gijang marine ranching area was partitioned into eleven transects (T1,T2,T3,T4,T5,T6,T7,T8,T9,T10,T11). During acoustic data collection the research vessel navigated starting from survey line T1 until T11 during both autumn (23rd September, 2017) and winter (11th November, 2017) surveys. The NASC values were extracted at intervals of 0.1nautical miles which represented the EDSU for the spatial and temporal distribution of fish in the small scale marine ranching area of Chilam-Gijang. For autumn surveys, the NASC intensities were between 1 to 50000 m^2/n.mile^2 , and most of NASC averages were clouded around T4 and T5 for both daytime and nighttime surveys. The rest of transects from T1 to T11 had intensities between 1 to 1000 m^2/n.mile^2. The NASC distribution during nighttime survey were between 50 to 250 m^2/n.mile^2 around T6 in autumn season. Comparing the NASC values, the nighttime survey had the NASC intensities of between 250 to 1000 m^2/n.mile^2 around T7 to T11 while daytime survey had relatively lower NASC intensities between 1 to 250 m^2/n.mile^2.

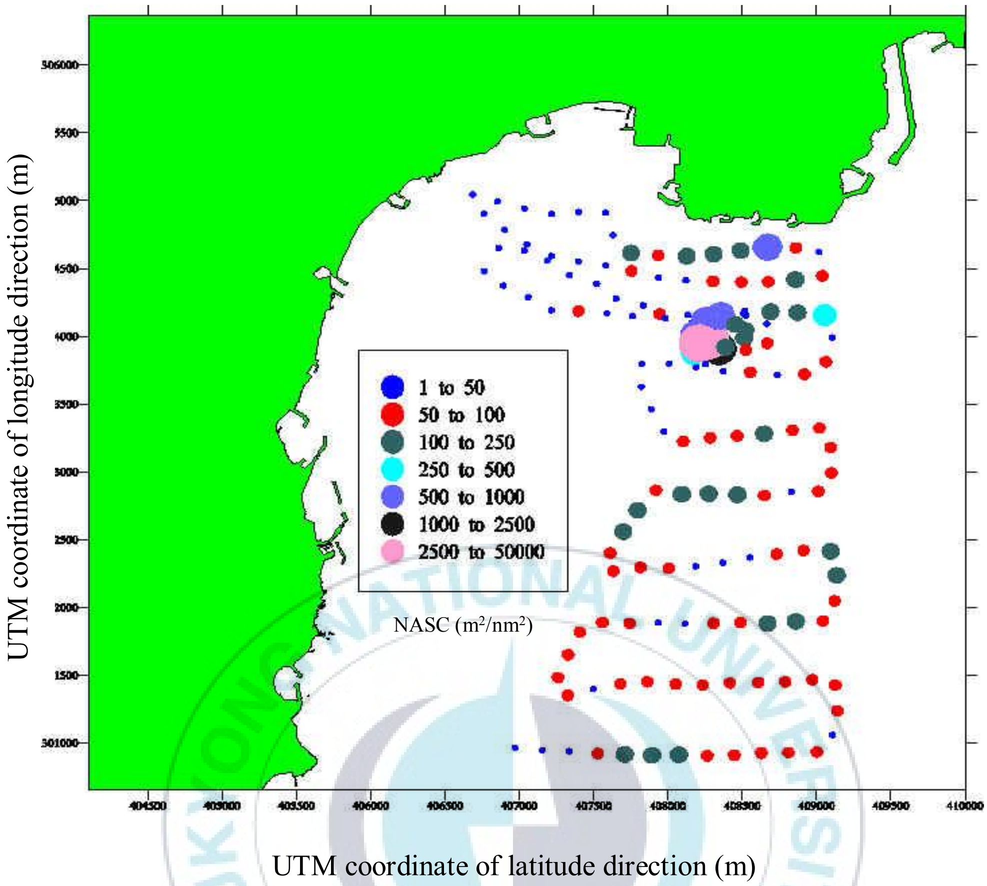

Figure 7. NASC distribution of fish schools during daytime surveys on 23rd September, 2017.

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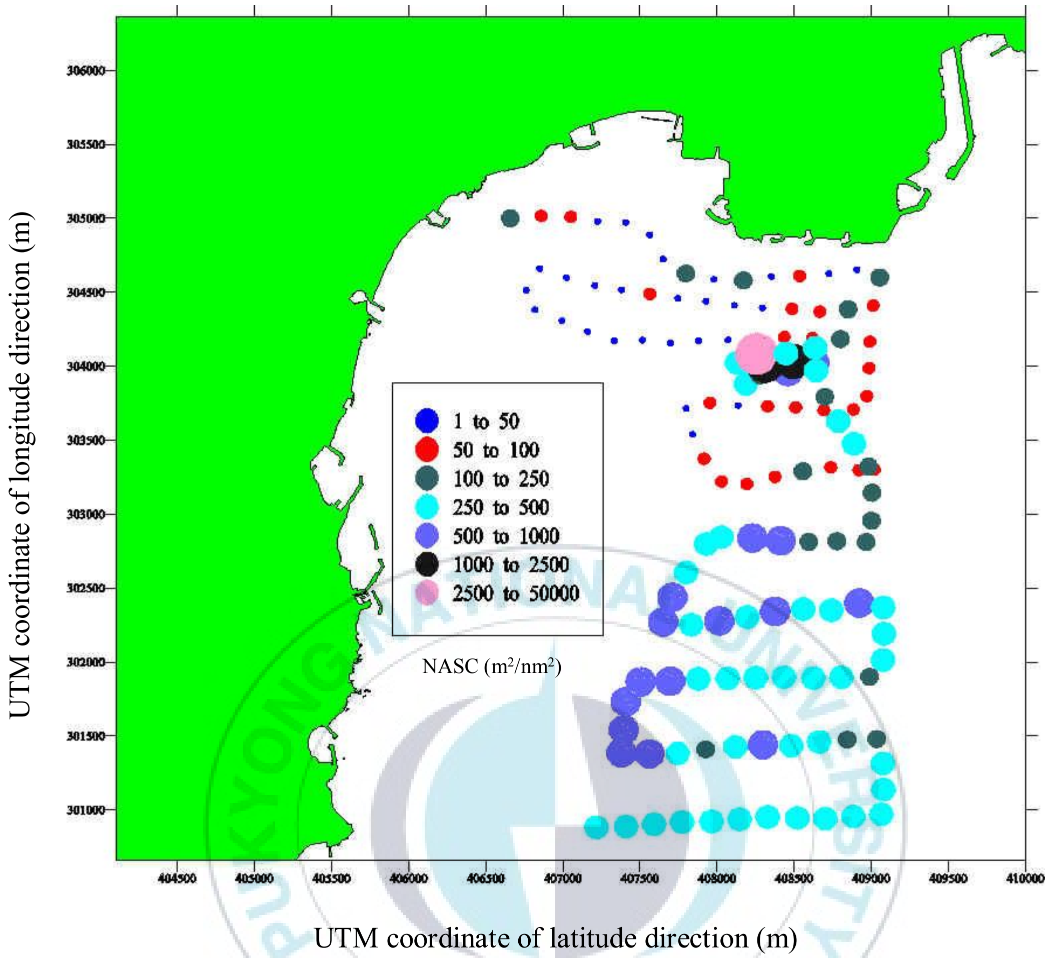

Figure 8. NASC distributions of fish schools during nighttime surveys on 23rd September, 2017.

The NASC intensities during winter surveys, the daytime NASC obtained around transects T4 and T5 were dominated by the NASC averages of between 1 to 50000 $m^2/n.mile^2$ and a few between 1000 to 2500 $m^2/n.mile^2$. The nighttime NASC distributions were same as daytime around T4 and T5. The NASC distributions recorded around T1 to

T3 were between 1 to 100 m²/n.mile². The NASC intensities around T7 to T11 were between 500 to 2500 m²/n.mile² during nighttime survey while daytime had between 1 to 250 m²/n.mile². Generally comparing and contrasting the surveys in two seasons, NASC distributions of autumn and winter around T6 to T11 for both daytime and nighttime surveys were almost the same. The NASC values around T4 and T5 for autumn were significantily higher and avarage NASC values were clouded as compared to winter around the same surveyed transects. Generally the NASC intensities of nighttime surveys were higher than daytime in both study seasons.

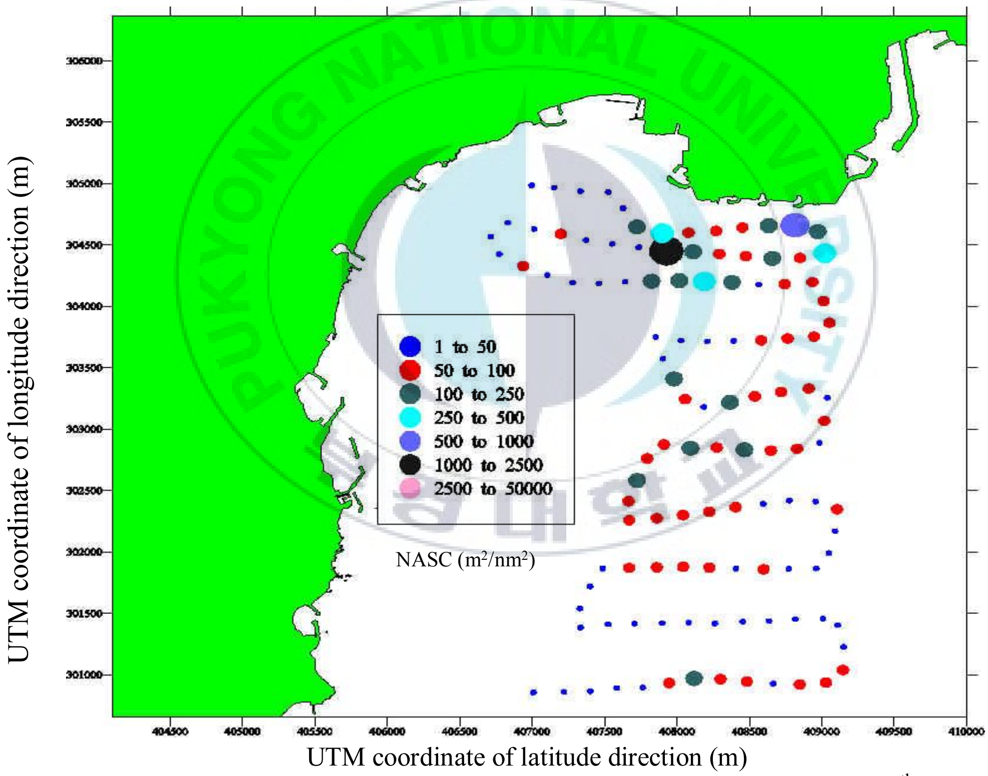

Figure 9. NASC distributions of fish schools during daytime surveys on 11th November, 2017.

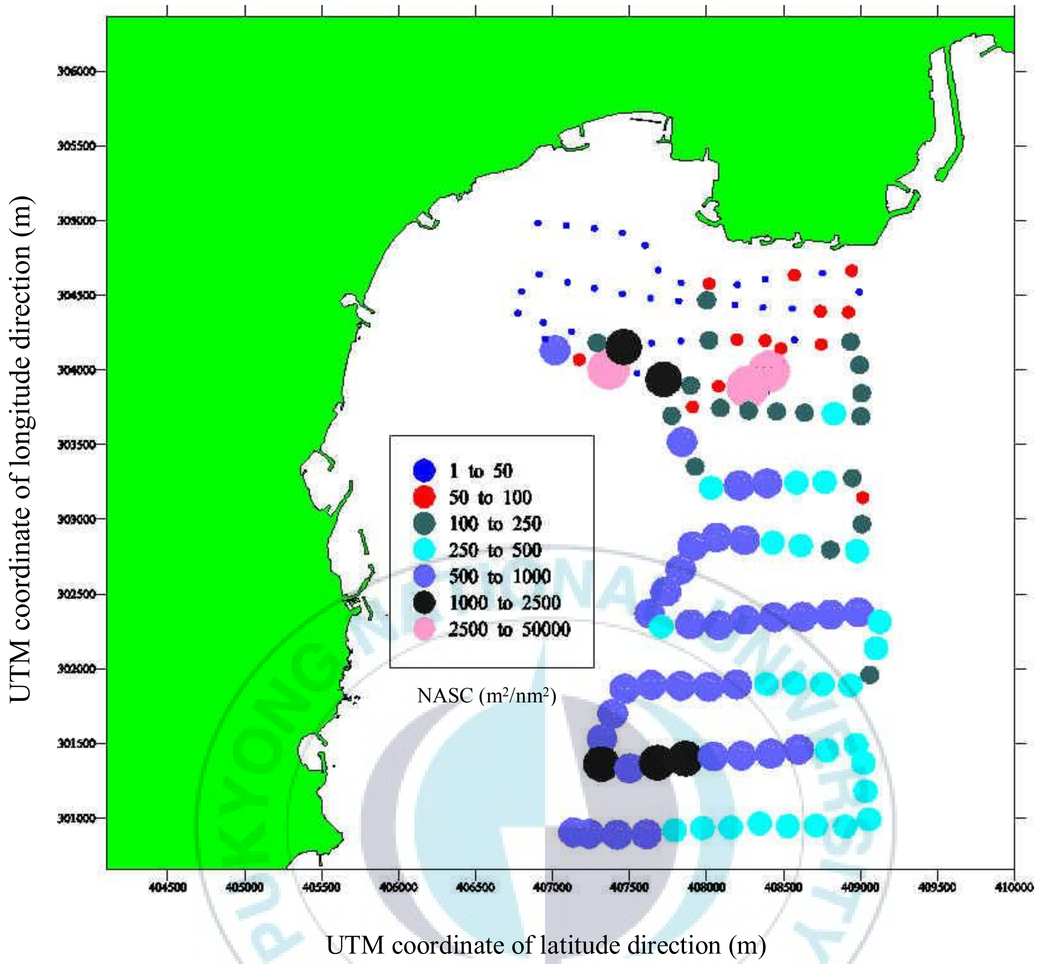

Figure 10. NASC distributions of fish schools during nighttime surveys on 11th November, 2017.

3.3. The catch composition and biometrics for the autumn and winter species

The caught fish species were 15 different groups of species which were identified during the gill net experiments in autumn and winter surveys. Along the water profile some species occupied the demersal layers while others inhabit pelagic layers. To derive the conversion factor, the five pelagic species were considered to have contributed the significant acoustic signals to be used in biomass calculations. These species included; *Scomber japonicus*, *Seriola lalandi*, *Ditrema temmincki*, *Pagrus major*, *Girella punctate* and *Monocentris japonica* for autumn gill net surveys. The other demersal species as seen in (Table 2), their echo signals contributed during data collection were ignored in calculation of the Conversion Factor.

Table 3. Fish species biometrics for autumn season surveys sampled on 31st August, 2017.

Water Zone	No.	Species name	Number of species	TL (cm)	AW (g)	TW (g)
	1	*Scomber japonicus*	9	22.7	128.0	1152.0
Pelagic	3	*Ditrema temmincki*	3	20.4	156.7	470.1
	4	*Pagrus major*	3	24.2	320.6	961.8
	5	*Girella punctate*	3	23.8	299.8	899.4
	6	*Monocentris japonica*	1	10.6	42.7	42.7
	7	*Sillago japonica*	1	25.2	97.4	97.4
	8	*Scorpaenodes littoralis*	1	20.2	168.7	168.7
	9	*Chelidonichthys spinosus*	10	26.8	201.2	2012.0
	10	*Platycephalus indicus*	9	44.7	589.2	5302.8
Demersal	11	*Pleuronectes yokohamae*	4	26.3	207.2	828.8
	12	*Argyrosomus argentatus*	3	15.4	42.3	126.9
	13	*Cynoglossus robustus*	1	35.0	301.7	301.7
	14	*Okamejei kenojei*	1	21.3	561.3	561.3
	15	*Okaraplagusia japonica*	1	26.0	208.3	208.3
	Total			57		17837.9

TL: Total Length, AW: Average Weight, TW: Total Weight

The caught fish species during winter gill net experiments were 15 different groups of fish species which were identified. Among these species some were pelagic and others demersal species. The pelagic species were; *Thamnaconus modestus, Ditrema temminckii*, *Sillago sihama, Zeus faber, Sebastes inermis* and *Trachurus trachurus.* These species ecologically dwell in the pelagic zone and their acoustic echo signals were used during calculation of Conversion Factor for the biomass calculations. The scattering intensity of the pelagic species had significant acoustic signals contributed which were used during biomass analysis. The demersal species identified (Table 3) are ecologically sea bottom species and their echo intensity contribution was considered negligible as their acoustic signals are obscured in the acoustic dead zone of the sea.

Table 4. Fish species biometrics for winter season surveys sampled on 31st October, 2017.

Water zone	No.	*Species name*	Number of individuals	TL (cm)	BW (g)	TW (g)
Pelagic	1	*Thamnaconus modestus*	5	20.9	125.9	629.5
	2	*Ditrema temminckii*	4	23.9	188.9	755.6
	3	*Sillago sihama*	3	22.1	78.3	234.9
	4	*Zeus faber*	2	29.4	341.1	682.2
	5	*Sebastes inermis*	2	24.6	278.0	556.0
	6	*Trachurus trachurus*	2	23.4	124.3	248.6
	7	*Oplegnathus fasciatus*	1	19.8	164.0	164.0
	8	*Stephanolepis cirrhifer*	1	22.4	205.7	205.7
Demersal	9	*Chelidonichthys spinosus*	8	32.0	308.4	2467.2
	10	*Pleuronectes yokohamae*	2	29.8	316.8	633.6
	11	*Argyrosomus argentatus*	1	23.6	169.7	169.7
	12	*Okaraplagusia japonica*	1	28.5	142.6	142.6
	13	*Cynoglossus robustus*	1	22.3	60.8	60.8
	14	*Hemitripterus americanus*	1	36.4	388.8	388.8
	15	*Paralichthys olivaceus*	1	50.0	1279.4	1279.4
	Total number		35			8618.6

TL: Total Length, BW: Body Weight, TW: Total Weight

The identified pelagic species in two study seasons, which had high frequencies were considered to contribute high signals of acoustics that had high echo scattering properties.

The fish total length and fork length were used to calculate the respective target strength of each of these species. The calculated target strength (TS) were as displayed in Table 4, and all selected pelagic species had the target strength in the ranges of -41 to -45 dB from autumn to winter surveys.

Table 5. Estimated target strength of individual fish species sampled on 31st August and 31st October, 2017.

Sampling season		Species name	Number of individuals	TL (cm)	BW (g)	TS (dB)
Autumn pelagic species	1	*Scomber japonicus*	9	22.7	128.0	-44.9
	2	*Seriola lalandi*	7	34.9	972.0	-41.1
	3	*Ditrema temminckii*	3	20.4	156.7	-45.8
	4	*Pagrus major*	3	24.2	320.6	-44.3
	5	*Girella punctate*	3	23.8	299.8	-44.5
Winter pelagic species	1	*Thamnaconus modestus*	5	20.9	125.9	-45.6
	2	*Ditrema temminckii*	4	23.9	188.9	-44.4
	3	*Sillago sihama*	3	22.1	78.3	-45.1
	4	*Zeus faber*	3	29.4	341.1	-42.6
	5	*Sebastes inermis*	2	24.6	278.0	-44.2
	6	*Trachurus trachurus*	2	23.4	124.3	-44.6

TL: Total Length, BW: Body Weight, TS: Target Strength

The weighted means for all the 11 transects were obtained from the NASC values of each transect. The Conversion Factor (CF) was calculated using the logarithmic equation by echo integration method. The total length and total weight for the selected particular pelagic species from catch were used in each season. Using the weighted mean, the Conversion Factor, Rho (ρ, g/ m^2) were calculated. The total surveyed area of 840 hectares was calculated using Arc GIS. The total biomass for the entire surveyed area in each season was obtained by multiplying the ρ (g/ m^2) values with surveyed area and then by 10000 metres in order to convert them into hectares. The total biomass for autumn and winter surveys were almost the same. Obtained biomass for nighttime surveys in each season was higher than that of daytime. Autumn had 7.7 tons and 26.0 tons for daytime and nighttime surveys, respectively. For winter surveys the obtained biomass was 2.3 tons and 31.0 tons for the daytime and nighttime, respectively. Comparing the biomass of the two study seasons, the daytime survey for the autumn biomass was higher than for winter (Table 4 and Table 5). The nighttime surveys for winter had higher biomass than the nighttime biomass of autumn surveys.

Table 6. NASC distributions on 23rd September, 2017.

Transects	Daytime		Nighttime	
	ni [1)]	NASC [2)]	ni [1)]	NASC [2)]
Transect 1	6	14.60	6	34.32
Transect 2	8	131.7	8	76.02
Transect 3	13	68.62	13	60.06
Transect 4	11	90.08	13	72.64
Transect 5	7	24.48	7	44.74
Transect 6	7	54.13	7	82.97
Transect 7	7	63.15	7	262.04
Transect 8	9	66.20	9	463.26
Transect 9	10	74.53	9	382.68
Transect 10	11	71.36	10	392.91
Transect 11	12	14.74	11	380.24
$\sum ni$	101	673.66	100	2251.88
Weighted mean-NASC	6.67		22.52	
Conversion Factor (CF)	0.1373		0.1373	
ρ (g/m^2)	0.916		3.091	
Survey area(ha)	840		840	
Biomass (ton) [3)]	7.7		26.0	
Coefficient of variation (%)	14.3		27.20	

[1)] Number of 0.1n. mile averaging intervals on the i_{th} transect

[2)]Mean backscattering area per 0.1 n.mile ^{2}

[3)]Mean biomass

Partitioning the echo integration to obtain the biomass contributed by each species, the highest biomass was contributed by *Seriola lalandi* which had 3.47 tons and 11.7 tons during daytime and nighttime of autumn surveys, respectively. The second highest biomass contribution was by *Scomber japonicus*, which had 1.89 tons and 6.37 tons for daytime and nigh time surveys, respectively. The rest of biomass portions contributed by each species was as displayed in Table 6.

Table 7. The estimated variables of surveyed species on 23rd September, 2017.

Species			Daytime		Nighttime	
	Partitioning EI	CF	ρ (g/m^2)	Biomass (ton)	ρ (g/m^2)	Biomass (ton)
Scomber japonicus	0.245		0.225	1.89	0.758	6.37
Seriola lalandi	0.451		0.413	3.47	1.393	11.70
Ditrema temmincki	0.066	0.1373	0.060	0.51	0.204	1.71
Pagrus major	0.093		0.085	0.71	0.287	2.41
Girella punctate	0.090		0.082	0.69	0.278	2.33
Other pelagic species	0.055		0.051	0.43	0.171	1.44
Total				7.7		26.0

EI: Echo Integration

Table 8. NASC distributions on 11th November, 2017.

Transects	Daytime		Nighttime	
	ni 1)	NASC 2)	ni 1)	NASC 2)
Transect 1	4	2.6	5	1.19
Transect 2	8	63.5	8	26.34
Transect 3	13	53.4	13	66.75
Transect 4	13	26.6	13	306.01
Transect 5	7	9.3	8	107.82
Transect 6	7	16.6	7	169.11
Transect 7	7	14.2	6	168.97
Transect 8	9	15.3	9	512.51
Transect 9	9	12.8	9	491.88
Transect 10	10	15.1	10	719.67
Transect 11	12	4.6	11	628.64
$\sum ni$	99	234.0	99	3198.91
Weighted mean-NASC	2.36		32.31	
Conversion Factor (CF)	0.1141		0.1114	
ρ (g/m^2)	0.270		3.600	
Survey area(ha)	840		840	
Biomass (ton) 3)	2.27		30.97	
Coefficient of variation (%)	14.0		28.0	

1) Number of 0.1n. mile averaging intervals on the i_{th} transect

2)Mean backscattering area per 0.1 n.mile ^{2}

3)Mean biomass

Partitioning the echo integration to obtain the biomass contributed by each species, the highest biomass was from other pelagic species which contributed about 1.01 tons and

13.48 tons during the daytime and nighttime surveys of winter season, respectively. Other pelagic species were; *Zeaus faber*, *Sebastes inermis* and *Truchurus trancurus*. The *Ditrema temminckii* had the second highest biomass of 0.46 tons and 6.73 tons during daytime and nighttime periods respectively of the same season. The rest of other fish species their biomass contributions were as shown in the Table 8.

Table 9. The estimated variables of surveyed species on 11thNovember, 2017.

Species	Partitioning EI	CF	Daytime ρ (g/m^2)	Daytime Biomass (ton)	Nighttime ρ (g/m^2)	Nighttime Biomass (ton)
Thamnaconus modestus	0.208		0.056	0.44	0.76	6.43
Ditrema temminckii	0.217	0.1141	0.059	0.46	0.80	6.73
Sillago Sihama	0.139		0.038	0.32	0.51	4.31
Other pelagic species	0.435		0.118	1.01	1.61	13.48
Total				2.23		30.97

EI: Echo Integration

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Discussion

4.1. Fish distributions in autumn and winter survey seasons

The NASC distribution in autumn and winter surveys, during the daytime fish schools were few and scattered near the sea bottom whereas during nighttime many fish schools were densely aggregated in the pelagic zone. At night most fish species are more active and experience several movements and migrations which affluence many detections recorded by the transducer during nighttime surveys. Landsman *et al.,* (2011); Mehner *et al.,* (2007) reported that during dark periods, there most predatory fish species hunt preys for food and some other species search for foods as water visibility is poor to be detected by predators. Diurnal vertical migrations among different fish species influence fish distributions, and the resulting estimated biomass varies accordingly. During nighttime high fish density distributions exhibit high acoustic signals in water column insonified by the echosounder (Burgos and Horne, 2007). The high frequency of the scientific echo sounder (EK60, 120 kHz) as compared to lower frequency has the effective higher resolution (Furusawa, 2015). At this resolution it was difficult to distinguish between two or more fish targets and therefore the recorded acoustic signals appeared as fish schools on echograms. The interference echoes caused by near sea surface air bubbles, noise from the vessel engines, propellers, and the detected sea bottom were eliminated during data cleaning. Through echo integration of the echogram, the bad data regions were eliminated to display regions with acoustic signals from targeted fish species. The displayed clusters of red and blue spots display regions on the echogram represented fish schools and individuals of fish. Echoes scatterings of fish schools depend on distances between the two fish targets, group of fish and the transducer position to the fish. When this distance is less than half the pulse length of the transducer, Simmonds and MacLennan (1992) reported that echoes received from fishes converge and are recorded as fish schools. This especially happen during nighttime when many fish schools are aggregated, and the distances between fish schools are less than half pulse length to the transducer. The echo integration method of acoustics is applied to analyze fish acoustic data (Simmonds and MacLennan, 2005; Grafe, and Joremy, 2017). When daytime sets in, fish tend to camouflage, stay away from predators as water is well illuminated during daytime periods (Lyons,1998). In this way preys defend themselves against predators which target them for food (Bode and Echevarria, 2014). This defense mechanism is exhibited by most marine and fresh water fish species in order to suitably survive in aquatic ecosystems with predators. Around Chilam-Gijang marine ranching area, the fish species were distributed in the pelagic zone during nighttime. Most of fish species are active during nighttime, and search for food across water profile since predators can hardly spot them for preys. Jung *et al*., (2011) explained how under water construction with artificial reefs, deployed in marine water increase the structural complexity of ecosystems. Artificial reefs effect the ecological activities of aquatic systems, provide suitable habitats for breeding and nursery grounds for fish, and attract fish food (aquatic plants and animals), Egerton *et al.,* (2018) reported habitat complexity and ecosystem interactions that enhance fish schoolings and density distributions. Around transects T4 and T5 many fish schools were aggregated around these transects as depicted by the overlapping NASC values. This meant the existence of high fish density distributions which could impact on fish biomass estimated around this area. The high fish densities observed between transects T6 to T11 during nighttime surveys of two seasons explain existence of different fish species that migrate and aggregate around this marine ranching area in particular time periods of the day. Lee *et al.,* (2012) reported that fish distribution around the marine ranching areas in Jeju Islands, different species were distributed around the artificial reefs up to the water depth of 20 m. These fish species are attracted around artificial reefs during movements, migrations, and some form fish schools around the marine ranching area. The surveys were conducted during both daytime and nighttime to enable assessment of any changes in spatial distributions over the diurnal cycle. These changes are experienced in many different aquatic environments with different fish species, thus demonstrate varying biological behaviours (Conti *et al.,* 2006; Gurshin *et al.,* 2009). This could be explained by the NASC distributions and high echo signals recorded during the nighttime surveys in two seasons around Chilam-Gijang marine ranching area. Many fish schools were distributed around transects T6 and T11 at the water depth from 10 m to the sea bottom. This is evidenced by the fact that most of artificial reefs were located off shores whereas transects from T1 to T5, less artificial reefs were installed around coastal shores. The coastal area is shallow, and part of water in this area was reserved for nuclear power plants, fisheries activities like ship docking and fisheries social economic activities in Gijang fishing village.

4.2. Fish species catch composition and estimated target strength

The catch from experimental gill nets for each season consisted of fifteen different fish species categorized into pelagic and demersal species. The individual species caught in autumn were higher in numbers as compared to winter individual species, which were 57 and 35 individuals identified in autumn and winter, respectively. The pelagic species identified in autumn were dominated by the *Scomber japonicus* and *Seriola lalandi*. Pelagic species during winter surveys were dominated by *Thamnaconus modestus* and *Ditrema temminckii.* The aggregations of fish species contributed to fish schools, as shown on each echograms especially during nighttime surveys. Fish distribution and target strength enable selection of acoustic threshold of targeted fish species (Burgos and Horne, 2007; Nakken and Olsen, 1977; Foote, 1987). The target strength for each of the pelagic species was estimated, and used in adjusting the threshold value and fish echo signals during data processing. This was through identifying echo characteristics reflected by fish species in acoustic beam basing on adjustments made in echoview analysis tool. Kang *et al.,*(2016) explained the application of fisheries acoustic characteristics in the studies of biological differences of fish species and their relationships with the target strength. The average target strength for pelagic species during autumn and winter were; -44.0 dB and-44.4 dB, respectively. The individual species of autumn season were slightly bigger in size than those of winter season, this could be explained by their observed differences in target strength. Target strength measurements through echo integration, convert fish acoustic waves into fish abundance for the particular surveyed area (Manik, 2015). Target strength quantitatively deduce information of fish species insonified by the echosounder. The higher target strength of fish, the stronger the echoes relative to transmission (Fornshell, 2013; Gurshin *et al.,* 2009). The target strength for each fish species was directly proportional to their respective sizes. *Ditrema temmincki*, *Thamnaconus modestus*, *Sillago sihama* and *Scomber japonicus*, had -45.8 dB, -45.6 dB, -45.1 dB and -44.9 dB respectively. Among the species identified in the gillnet surveys of autumn and winter, the pelagic species; *Scomber japonicus* was largest and the least in size being *Ditrema temmincki.*

4.3. The estimated fish biomass in different surveys

In surveys during autumn and winter seasons, the estimated fish biomass of nighttime was significantly higher than that of daytime. The estimated fish biomass in autumn were 7.7 tons and 26.0 tons during the daytime and nighttime surveys respectively. Winter had the 2.27 tons and 30.97 tons, daytime and nighttime respectively. The daytime survey of autumn had higher fish biomass than that of winter survey whereas the nighttime surveys during winter had higher biomass than nighttime surveys of autumn season. Changes in estimated fish biomass between seasons and time of the day is influenced by fish behaviours that vary with seasonal changes (Guillard and Vergès, 2007; Godlewska *et al.,* 2009). Fish diurnal movements and migrations simultaneously influence fish biomass especially during biomass studies (Landsman *et al.*, 2011). During diel vertical migrations different fish species occupy varying water layers influence the estimated fish biomass for particular species (Tables 5 and 7). Daytime periods most fish stay near the sea bottom, and the demersal species which dwell close to the sea bottom in the acoustic dead zone (Mehner *et al.,* 2007). In acoustic dead zone the fish acoustic signals are obscured by the sea bottom and end up being discarded yet would have been of importance in contributing to the fishes acoustic waves needed in biomass calculations (Mello and Rose, 2009). Djmali *et al.,* (2010), fish schools and individuals of fish are less during daytime, the nighttime acoustic data collection increases chances of fish detections by the transducer. Under water construction with artificial reefs enhance fish biomass and fisheries productivity through habitat expansion and modification. Carr and Hixon, (1997); Egerton *et al.*, (2018), reported that artificial reefs attract different fish species as spawning grounds for brood stocks, act as the nursery grounds, habitats for fish preys and phytoplanktons. Different fish species were distributed around several artificial reefs in surveyed transects found Chilam Bay. Fish distributions impact on fish biomass estimated in different times and space around Chilam Bay. Biodiversity interactions with installed artificial reefs restore the abundance of aquatic plants, animals and the ecosystems structure (Jennifer, 2008; Aburto-Oropeza *et al.,* 2011). Around Gijang fishing village many nuclear power plants and other many fisheries commercial activities are ongoing, some of these affect the fisheries productivity as they anthropogenic activities. To enhance the fisheries productivity and habitat restoration, (Karjalainen and Marjomäki, 2005) explained sustainable aquatic resource utilization and management. Korean government installed several artificial reefs around Gijang coastal areas to the distance of about 14.9 nautical miles in Chilam marine waters. However from transects T1 to T5 in both autumn and winter surveys the fish schools were few and scattered as shown on echograms (Figures 4, 5, 6, and 7). Near shores marine water is utilized by nuclear power plants and also the ongoing anthropogenic activities hamper fish colonization of artificial reefs. From T6 to T11 many fish schools were aggregated which could explain fish colonization of artificial reefs, this influence fish biomass and fisheries production. Partitioning the total biomass of all identified fish species through echo integration method, the species which contributed the highest biomass in autumn was *Seriola lalandi* with 3.47 tons and 11.7 tons during daytime and nighttime surveys, respectively. The second highest contribution was from *Scomber japonicus* and 1.89 tons and 6.37 tons during daytime and nighttime surveys respectively. The rest of biomass portions for each species was as displayed in Table 6. Sang *et al.,* (2016), reported about the spawning of *Seriola lalandi* in periods of spring and summer around the coastal areas. This specie is diadromous during breeding periods which might explain the high fish density distributions and biomass in autumn surveys that proceeds after summer on Korean Peninsula. For winter surveys other pelagic species contributed the highest biomass of 1.01 tons and 13.48 tons during daytime and nighttime surveys, respectively. Other pelagic species group consisted of; *Zeus faber*, *Sebastes inermis, Trachurus tranchurus*, *Oplegnathus fasciatus* and *Stephanolepis cirrhifer*. *Ditrema temminckii* had the second highest biomass of 0.46 tons and 6.73 tons during the daytime and nighttime surveys respectively.

The relationship between survey design and sampling error was expressed in terms of the degree of coverage with the proportions of observed biomass in the total area surveyed. The all surveys in autumn and winter had the degree of coverage of 6.7 and 6.5 for daytime and nighttime surveys, respectively. This means that the total surveyed area was sufficient to provide a good representation of the estimated fish biomass in Chilam Bay. The greater the degree of coverage, the better results. The total surveyed area was 840 hectares, according to Aglen (1989) the degree of coverage explain the relationships between the total length of the survey lines, surveyed area, number of the survey lines, length-width and intervals between survey lines.

Monitoring the environmental water parameters around surveyed transects with artificial reefs, the current speed and direction recorded were in normal ranges which could not interfere with acoustic with survey design and acoustic data correction process. The physical-chemical water parameters; temperature of 17.5 ° C, dissolved oxygen of 8.7 mg/L, conductivity of 33.5 psu and Turbidity of ~1.0 NTU were recorded by RCM9. Helge, (2002) suggested the effects of, pressure, temperature and salinity on acoustic waves. The temperature difference of about 10 ° C show larger errors of 0.2 dB, thus during acoustic surveys, the temperature variation was too low to have any influence on the speed of acoustic waves. The proper adjustments of the transducer gain basing on current speed and direction, this eliminates the errors during acoustic data recording. The environmental parameters affect biological behaviours of around the study stations, which was not a major objective of this study and this bay has shallow waters of 50 m as the maximum depth.

4.4. Conclusions and recommendations

Comparing the fish density distribution, autumn had higher fish distributions than those of winter on the surveyed days. The NASC distributions obtained during nighttime surveys were higher than those obtained during daytime surveys for the two seasons. Generally during daytime fewer fish schools or individuals of fish were near the sea bottom whereas during nighttime, they were aggregated and distributed in water pelagic zone.

The experimental gill nets' catch comprised of 15 different groups of fish species that were caught for each survey season. Each season had different fish species among which some were pelagic species and others the demersal species. The fish morphometrics of demersal species were ignored during calculation of conversion factor for biomass estimation, their echo signals were obscured by the acoustic dead zone of sea. The target strength estimated was for the pelagic species that contributed significant echo signals, which were considered after acoustic data cleaning. The estimated target strength for autumn and winter pelagic species were -44.0 dB and -44.4 dB, respectively.

Acoustic surveys during data recording in different seasons enabled collection of acoustic signals from all different fish species in Gijang marine ranching area found in Chilam Bay.

This implied that biomass estimated during the nighttime were close to actual existing biomass of all pelagic fish species in Chilam Bay.

This study considered the pelagic species only during target strength estimation and conversion factor calculations for the estimation of fish biomass from acoustic signals. Further research studies on demersal species using the underwater visual census, water cameras to record data directly on these species, bottom trawls and traps were recommended for proper biomass estimation of all fish species identified. The fish biometrics studies about maturity status, fish age, fecundity and sex ratios to explore more factors leading to population dynamics in marine ranching area of Chilam Bay. Continued, time and space fisheries acoustic data collection to monitor the impacts of artificial reefs progressively in Chilam Bay were recommended. This would guide all the fisheries stakeholders on fishery management through proper resource exploitation.

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